it should have been stated on p. 91 that the original idea of the spectroheliograph was due to Dr. Janssen, who first suggested it at the Exeter meeting of the British Association in 1869. Again, with reference to the first observation of the spectrum of a nebula, it is stated (p. 242) that "it was seen at a glance that the spectrum consisted of a few bright lines," though the observer at first attributed what he saw to some possible derangement of his instrument.

Looking forward, Prof. Turner believes that, among other changes, the transit circle will be gradually superseded by the almucantar for star observations, and by the heliometer for observations of the positions of planets, and in celestial photography he predicts a great future for the portrait lens.

The illustrations, some thirty in number, are of indifferent quality, and that of Eros, on p. 109, is almost unintelligible.

Chemistry an Exact Mechanical Philosophy. By Fred. G. Edwards, Inventor of Atomic Models. Pp. xii + 100. (London: J. and A. Churchill, 1900.)

"THE object of this work is to determine the exact shape of the atoms, to find their relative position in space, and to show that chemical force is purely a function of matter and motion." Further, "the shapes obtained for the different atoms is the subject-matter of a British patent (atomic models) dated 1897." Again, "the conclusions herein deduced (when accepted as true) will form a fitting climax to the discoveries of a century which has produced the atomic theory of Dalton, the theory of heat as a mode of motion, and the discoveries of the correlation of physical forces, and that force, like matter, is indestructible."

For the scientific reader there is little need to add any comments to these quotations. There is, however, always the possibility that an author may have a good idea but an unfortunate way of presenting it, and one does not forget that "the law of octaves" was received with something like ridicule. It is necessary to add, therefore, that a careful examination of the present work, made with every desire to find precious metal in it, has failed to reveal anything that seems likely to aid the advancement of science.

In dealing with the *exact shape* of atoms, the author starts with the assumption that the lightest known element, hydrogen, consists of two tetrahedra placed base to base, and that the atoms of the whole of the remaining elements may be similarly formed by tetrahedra built up symmetrically, every two tetrahedra representing one unit of atomic weight. It is practically impossible, without the models before one, to judge whether there is any outcome from this view of things that compensates in any degree for its arbitrariness and complexity. There can be little question, however, that as a whole the book and its doctrines will not command the serious attention of men of science whose leisure and patience are limited. A. S.

The Chemists' Pocket Manual. By R. K. Meade, B.S. Pp. vii + 204. (Easton, Pennsylvania: The Chemical Publishing Co., 1900.)

A LARGE amount of information of use to professional chemists is brought together in this pocket book. The tables include almost everything to which occasional reference has to be made in chemical laboratories; and with the formulæ, calculations, physical and analytical methods, should be of service not only to chemists, but also to assayers, metallurgists, manufacturers and students. Among the points worthy of special mention are the applications of graphic methods to conversion tables; and the descriptions of select methods of technical analysis.

LETTERS TO THE EDITOR.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, or to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

The Use of the Method of Least Squares in Physics.

THE application of the method of least squares to physical measurements is described in several standard text-books—to wit, Kohlrausch's "Introduction to Physical Measurements" (third edition, 1894), Stewart and Gee's "Elementary Practical Physics" (1885), and others. In none of these is it pointed out that the method *as set forth* offers in certain cases a choice of results, and that the solution is practically unique only if a sufficient number of observations be taken. Nor is any indication given how the method is to be applied when none but a small number of observations is available. Since the method is intended for use only when a high degree of refinement is aimed at, these points are of practical importance.

As illustrating the necessity for examining the matter, we may take the example given by Kohlrausch on p. 13 of the book referred to above. The object is to determine the law connecting the length L and temperature θ of a standard metre bar from the following four observations:—

θ . . . . = 20°, 40°, 50°, 60°

l (the excess over 1 metre) = ·22mm., ·65mm., ·90mm., 1·05mm.

The law deduced is

$$L = 999{\cdot}804 + 0{\cdot}0212\theta.$$

It is not, however, pointed out that the law would be different if the equation connecting x and y, in this case θ and l, were written to begin with in a slightly different form. On the contrary, the above solution is presented as if it were altogether beyond doubt.

In the working of the example as given by Kohlrausch, the equation is written

$$y - ax - b = 0;$$

but if it be written

$$cy - x - d = 0,$$

and exactly the same procedure as that adopted in evaluating a and b be followed in determining c and d, the law thence deduced from the observations becomes

$$L = 999{\cdot}800 + 0{\cdot}0213\theta.$$

It will be seen that the constants in these two laws differ by one in two hundred, or 0·5 per cent., as regards the significant figures; and that from the precisely similar way in which they are obtained, they are each equally entitled to recognition.

In fact, corresponding to the values for a and b usually given, viz.:—

$$a = \frac{\Sigma x \Sigma y - n\Sigma xy}{(\Sigma x)^2 - n\Sigma x^2}; \quad b = \frac{\Sigma x \Sigma xy - \Sigma x^2 \Sigma y}{(\Sigma x)^2 - n\Sigma x^2},$$

there are always another pair of values, giving the second form of the law, viz.:—

$$a' = \frac{(\Sigma y)^2 - n\Sigma y^2}{\Sigma x \Sigma y - n\Sigma xy}; \quad b' = -\frac{\Sigma y \Sigma xy - \Sigma y^2 \Sigma x}{\Sigma x \Sigma y - n\Sigma xy}.$$

The first pair of values corresponds to the supposition that the x measurements are guaranteed correct, and the experimental errors are all confined to the y measurements; and the second pair corresponds to the supposition that the y measurements are correct and the errors are all in the x measurements. The two lines

$$y = ax + b$$
$$y = a'x + b'$$

intersect at the centre of mass of the system of points obtained by plotting the observations.

The question naturally arises: How shall a relatively small number of observations, or a series of observations which are relatively discordant, be made to furnish the best mean result obtainable when no other observations are available?

In order to answer this question, we may recur to the remark above that differences in the result are obtained by writing the equation in different forms. The various forms of the equation correspond to the several directions in which the divergencies of

the plotted observations from the graph of the law are to be considered. For instance, when the equation is written

$$y'_1 - ax_1 - b = \delta',$$

the divergence δ' is measured along the ordinate; but when it is written

$$cy_1 - x_1 - d = \delta'',$$

the divergence δ'' is measured in the direction of the abscissa. Now if the divergencies were measured at right angles to the graph, and the sum of the squares were made a minimum, the graph would be the principal axis of inertia of the system of points. This line passes through the intersection of the other pair of lines, and gives a smaller sum of squares than any other line. When the number of points is very great, all three lines become sensibly coincident.

We may conclude, then, that when the observations are numerous and fairly concordant, the method of least squares, applied in the manner commonly taught, will give a practically unique result. But if in any particular case there be any doubt on this point, by reason of the number of observations being small, or the discrepancies between the observations being very great, it would appear to be desirable to find both the lines corresponding to the values of a, b and a', b', given above, in order to test the question. In the event of the difference between the pairs of constants obtained not being negligeable, the proper line to be made use of, in preference to either of the two others found as above, would seem to be the principal axis of inertia.

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The Collection of Material for the Study of "Species."

STRANGELY enough, while the publication of "The Origin of Species" and the research which has been carried on since Darwin wrote his epoch-making work have completely revolutionised the morphologist's conception of what is a "species," nearly all the "systematic" work which is published even at the present day, especially in those branches of biological science where the amateur collector exerts most influence, is based upon the principles founded by Linnæus. These principles, while they were perfectly logical in pre-Darwinian days, are now, however, quite obsolete and out of harmony with the current state of biological knowledge. With a view to bringing scientific practice more into accord with scientific theory, a paper to which I listened at a recent meeting of the Linnæan Society suggested a reform in the present system of species nomenclature. Since, however, the great majority of those who describe "species" are unfortunately not in a position to realise how great indeed is the necessity of some such reform, it will probably not obtain immediate support from the systematists. The average "systematist" still holds the pre-Darwinian view of "species"; and, as the great bulk of the material at his disposal in public and private collections is of little value for the proper study of taxonomy, he quite fails to see how absolutely untenable his position really is. He does not realise how utterly impossible it is in certain groups to assign limits to the variability of "species," and it will never occur to him that two specimens superficially alike in all respects may quite possibly have been evolved along entirely different paths.

It is not my intention here to enter into a discussion as to whether a system of provisional names, such as is suggested by Mr. Bernard, might not be of distinct advantage in at least some branches of zoological inquiry; what I do wish to call attention to now is the necessity, if any decided advance is to be made in the study of taxonomy, for a sweeping change in the present system of collecting material, and in its representation in collections. The following remarks bear particularly upon the case of the mollusca, of which group I have personally most knowledge, but they are, of course, more or less applicable to other branches.

The taxonomist requires as a basis for his investigations to know as exactly as may be the range of variation which those forms in which he is interested experience at the different stations over which they occur. This knowledge is obviously most satisfactorily acquired by personal observation on the spot; but, as this is seldom practicable, the student is in general forced to rely upon material collected by others. Unless this material has been properly collected, the conclusions based upon it are likely to be erroneous; and most of the material available to the student of such groups as the Mollusca is eminently unsatisfactory. Apparently the aim of many conchologists is to represent (?) in their collections the greatest possible quantity of "species," each by a certain definite number—usually three—of "fine specimens." These may be as unlike the ordinary examples of the form as can be; and, whether they are localised or not is of little account, so long as they be fine. If a larger or more brilliantly coloured specimen is obtainable it replaces one of the mystic three.

Large Series necessary.—Little can be known about a species until large series have been examined; yet a collector or museum curator almost invariably prefers a "new species" to a specimen which might lead to a clearer understanding of others already in the collection. Again, in most museums two or three shells, for instance, are considered to amply represent a species. When one has only a few examples under examination it is a fairly simple matter to assign these to so-called species; but the task becomes very different when one comes to deal with a large series, particularly if the specimens are from different localities. In all groups the range of specific variability is very much greater than will be admitted by those who confine their attention solely to museum specimens: in the case of the marine Mollusca, it is often quite easy to select from a large gathering of a single species two or more series which will readily pass as distinct species if the intermediate forms are suppressed. In the past, many "species" have been thus formed; and, if rumour speaks truly, this has sometimes been done quite knowingly, the connecting forms having been carefully destroyed; though more generally it has arisen inadvertently through the study of insufficient material. Again, a museum series, in addition to demonstrating the range of variation of a form, should also illustrate its life-history; but only too frequently an immature individual is regarded by the collector as a "bad specimen" and thrown away as valueless.

Exact Localities.—The most important consideration in a collection is that every specimen shall be accurately localised, and the more minutely the exact locality has been recorded the more valuable will the specimen be for study. At the present day, perhaps, few collectors are satisfied with such records as "Australia" or "America," but such scarcely less vague ones as "S. Africa," "W. Indies," &c., are to be commonly met with; and specimens with inexact localities, or without any record at all, abound in our museums. One unsatisfactory feature about specimens purchased from dealers is that there is a temptation for the dealer to suppress the true origin of his specimens.

Those whose knowledge of species has been derived mainly from museum specimens seldom realise how greatly these species often vary in relation to their environment. Thus, in the case of the marine Mollusca, specimens obtained from the sandy portions of a shore will frequently differ perceptibly from others of the same species collected on the neighbouring rocks or mud. By keeping the series from different stations distinct, the collector will often be surprised at the considerable local variation which his specimens will manifest.

Fossil and Recent Forms.—The treatment of palæontology as a distinct science is one of the greatest obstacles in the way of a proper appreciation of the problems of taxonomy. In most museums, as in our own National collection, the fossil forms of a group are widely removed from their recent allies; and the not unnatural result is that writers on existing species of, say, the Mollusca, seldom make even the slightest reference to fossil members of the group. A true knowledge of the relationships of the living members of any group *can* only be attainable by the study of those forms which have preceded them in the process of evolution; and this research will be greatly simplified when recent and fossil forms can be examined side by side. The comparison of recent specimens with the closely related subfossil ones from the same locality and elsewhere is of most particular importance, but is as yet seldom possible.

The Condition of Specimens.—Among conchologists, and in this respect they are almost the only sinners, insufficient attention is generally paid to the condition of the specimens. The collector of shells too often prefers to gather up the miscellaneous débris of a "shell beach" rather than search for living examples, and unfortunately he is in the habit of founding "species" upon material so obtained. A very large percentage of Molluscan species has been based upon single, dead and unlocalised specimens: what wonder that so many of their names are absolutely worthless?

"*Faking*" *Specimens.*—Any interference with the natural